POTENTIAL INFLUENCE OF COURTYARD ON INDOOR ENVIRONMENT CONDITIONS OF OFFICE BUILDINGS

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In the name of God, The Most Gracious, The Most Merciful

For my late father and mother, my brothers and sisters

For my friends who support me during this journey.

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بِسَــمِّ اللهِ الرَّحْمَـنِ الرَّحِيـم

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ABSTRACT

It is recognized that the air conditioning system is a major factor that influencing energy consumption in Malaysia. In fact, residential and non-residential buildings, become a subject to significant cooling necessities due to the high intensity of heat passing from building external envelope, the rely on mechanical cooling systems to provide best indoor condition was directed to increase the energy consumption. Due to this fact, many designers highlighted the potential influence of courtyards as a natural cooling technique to enhance indoor comfort for building users and consequently minimize space-cooling conditioning. This research investigates the courtyard attributes as a natural cooling technique in tropical climates, to provide indoor thermal condition at single, double and three-story buildings; furthermore, to achieve low energy office buildings in Kuala Lumpur and Johor. The research objectives are to investigate the history of the courtyard in Malaysia, to evaluate indoor environmental conditions at office buildings and finally to assess, the effectiveness of a courtyard on conserving energy in office buildings in Malaysia. The research method is a combination of literature review, environmental measurement, post occupancy evaluation and energy consumption data. To achieve the first objective of this research previous study assessed to gain information of the courtyard at vernacular architecture, contemporary vernacular and modern architecture in Malaysia, it started before independence in 1957 and transformed through time until the dawn of the new millennium. Furthermore, several environmental aspects such as air temperatures, relative humidity, and air velocity were measured using a portable instrument (Lutron LM 8000) and thermal comfort station (BABUC A). Whereas, the post-occupancy evaluation used to assess the level of indoor thermal condition at office buildings, at least, the energy data examined through the electricity bills for the at least one-year period. According to the last findings of this

research, the influence of the courtyard on providing indoor thermal conditions achieved at single and three storey buildings, while for double storey building the indoor condition did not comply with ASHRAE- 55 and ISO 7730 standards. For the term low energy office buildings, the results illustrated that single and double storey office buildings considered as low energy office buildings, while for three storey office buildings the amount of energy that used did not comply with MS 1525 standard.

ABSTRAK

Sistem penghawa dingin dikenali sebagai faktor besar yang mempengaruhi penggunaan tenaga di Malaysia. Hakikatnya, Bangunan kediaman dan bangunan bukan kediaman, menjadi subjek kepada kepentingan keperluan penyejukan kerana keamatan haba yang tinggi beredar daripada ruang envelope bangunan. Kebergantungan kepada system penyejukan mekanikal untuk menyumbang kepada keadaan dalaman yang terbaik hanya ditujukan untuk meningkatkan penggunaan tenaga. Makanya kerana hakikat ini, ramai pereka menegaskan potensi pengaruh halaman sebagai teknik penyejukan semulajadi untuk meningkatkan keselesaan dalaman, seterusnya, mengurangkan ruang penyejukan penghawa. Kajian ini mengenalpasti ciri-ciri halaman sebagai teknik penyejukan semulajadi dalam iklim tropika, untuk memberi keadaan thermal dalaman untuk bangunan setingkat, dua(2) tingkat dan tiga(3) tingkat. Selain itu, mencapai bangunan pejabat tenaga rendah di Kuala Lumpur dan Johor. Kajian ini mengenalpasti sejarah halaman di dalam Malaysia, untuk menilai keadaan dalaman alam sekitar di dalam bangunan pejabat di Malaysia. Kajian metadologi ialah gabungan kajian literatur, pengukuran alam sekitar, penilaian penghunian lepas dan data penggunaan tenaga. Untuk mencapai objektif pertama kajian ini, kajian lepas dinilai untuk mendapatkan maklumat halaman dalam seni bina vernakular, seni bina kontemporari dan seni moden di Malaysia, yang bermula sebelum kemerdekaan pada tahun 1957 dan berubah mengikut peredaran masa sehinggalah millenia baru. Tambahan itu, beberapa aspek alam sekitar seperti suhu angin, kelembapan relative, dan kelajuan angin telah diukur menggunakan alatan boleh gerak (Lutron LM 8000) dan stesen keselesaan haba (BABUC A). Manakala, penilaian penghunian lepas digunakan untuk menilai tahap haba keadaan dalaman di dalam bangunan pejabat, seterusnya data tenaga diperiksa melalui bil elektik dalam masa sekurang-kurangnya setahun. Mengikut kajian sebelum ini, pengaruh halaman menyumbang kepada keadaan dalaman haba dalam banguna

setingkat dan bangunan 3 tingkat, manakala, bangunan 2 tingkat pula tidak memenuhi standard ASHRAE- 55 dan ISO 7730. Hasil menunjukkan bangunan setingkat dan bangunan 2 tingkat dikategorikan sebagai bangunan haba rendah, manakala bagi bangunan 3 tingkat, penggunaan tenaga tidak memenuhi standard MS 1525.

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LIST OF SYMBOLS, ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating and
CIBSE	Chartered Institution of Building Service Engineers
EE	Energy Efficiency
EEI	Energy Efficiency Index
GBI	Green Building Index
GEO	Green Energy Office
HAVC	Heating, Ventilation and Air Conditioning
IEQ	Indoor Environmental Quality
KL	Kuala Lumpur
NGO	Non- Government Organization
MDU	Multi Dwelling Unit
LEO	Low Energy Office
POE	Post Occupancy Evaluation
PWD	Public Works Department
PMV	Predicted mean vote
PPD	Predicted Percentage of dissatisfied
RH	Relative Humidity
T_a	Air Temperature
V_a	Air Velocity
SPSS	Statistical package for Social Science
Stand.Dev.	Standard deviation
SET	Standard Effective Temperature

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CHAPTER 1

INTRODUCTION

1.1 Research Background

It is now recognized that the effectiveness of energy is becoming a vital issue, as energy has become under serious shortage in the next future (Sadeghifam *et al*., 2015). Thus, there is a continuous increase in energy production in an urban area, due to growing populations who appreciate the higher material prosperity and life standard (Wee *et al*., 2008). Many reports on the energy consumption revealed that commercial, institutional, industrial and residential building sector consumes a huge amount of energy every year, as a result the pattern of energy consumption will likely increase sharply next years. However, since the 1970s, building developers, engineers and architects are better aware towards design strategies that lower energy usage (Moghimi *et al.*, 2011).

The movement focused towards finding effective passive strategies to bring down the energy demands of buildings, and encourage further awareness of energy-conscious invention. The outcome of this step that the designers became more aware of old strategies that depend on non-mechanical methods, in order to improve the comfortable atmosphere. For an example in hot-dry and warm, humid zones cooling is a priority than heating, for this demand many elements support natural techniques applied in these buildings for many decades, such as courtyards, mashrabiyya, wind towers and ventilation tunnel (Noble, 2007). Noble in his study focus on the cooling techniques around the world, he found that in hot, dry and humid regions, vernacular design techniques involved elements in providing a cooling environment such as (high opening window, building orientation, shading device), while in the United State of America, ventilation tunnel is popular in the region. In Middle Eastern countries mashrabiyya and

ventilation through water elements used in a humid area, whereas in the dry area they used wind tower and courtyard.

This research will focus on the courtyard as an element that provides the cooling to the building. The significant role that played by the courtyard in building design of many regions, shown during warm weather (Muhaisen, 2006). The elements of the courtyard have unique advantages in hot and humid climates as passive cooling systems, which has ability to cooling the building and offers the thermal comfort for users'(Sadafi *et al.*, 2008). After many attempts of examining this tool, designers started to introduce the benefit of the courtyard on the first stage of building design, especially in green building and offer the best techniques that compatible with the building elements to gain significant impact of the courtyard.

However, during the construction or building refurnished, the elements of the courtyard as landscaping and water features could add to the building environment without change the structure of the existing building. Various efforts conducted field measurement or computer simulation, in order to improve energy efficiency in the buildings by incorporating courtyards as passive cooling technique.

1.2 Problem statement

Nowadays, most governments have made repetitive requests for preservation energy as well as global warning after the Kyoto protocol of 1997 was singed (Sadeghifam *et al*., 2015), and one of these countries is Malaysia. The traditional Malay buildings were designed according to the local needs and respects for nature; therefore, it is not surprising to find that the traditional house in the Peninsula can adapted natural strategies in ventilation, lighting and cooling (Ismail, 2007).

After Independence in 1957, Malaysia has developed in the economy, which in recent years, has successfully transformed from an exporter of raw materials into a diversified economy, this makes the country perceived speed development in all aspects, especially in construction. The desire to outline the architectural image of new nation leads to adapt the international style for the architecture of non-residential and residential buildings (Ju & Omar, 2011), according to Bakar *et al.*, (2015), the increase in the number of modern buildings in Malaysia has an effect of the energy demand.

Another essential point is the climate characteristics of Malaysia, which caused the general temperature during daytime between 20°C to 32°C, while during night it reduced to 21°C to 27°C, with relative humidity around 75% to 90% and never went under 60%. Therefore, residential and non-residential buildings are subject to significant cooling necessities due to the high intensity of heat passing from building external envelope, the rely on mechanical cooling systems to gain indoor thermal comfort was directed to increase energy consumption. In fact, the percentage of electricity growth reached to 30% after 1st June 2006 (Puteh, 2007).

From the above points, this research focuses on reducing energy consumption in buildings by finding natural cooling techniques, in this research is to study the potential influence of courtyard in tropical climate in order to provide indoor thermal conditions and achieve low energy office.

1.3 Research questions and Hypothesis

This part deals with the research questions and the hypothesis that will address the objectives of this research, as listed follows:

Q1. Does the effectiveness of courtyard area will succeed to provide a comfortable indoor environment in an office building?

- **Hypothesis 1: An Office building with a courtyard has a better indoor environmental condition as required by standards.**

Q2. Does the introduction of courtyard area in an office building will be effective to reduce the total of energy usage?

- **Hypothesis 2: The potential of the courtyard to lower energy consumption will efficiently reveal at single storey office building with full shade courtyard.**

1.4 Research objectives

The aim of this research is to study the potential influence of a courtyard building, whichever as natural cooling technique, or as a micro- climatic regulator in hot-humid climates. The objectives of this research are as follows:

i. To investigate the courtyard history in Malaysia, through vernacular, contemporary vernacular and contemporary building design.

ii. To evaluate indoor thermal conditions of single, double, and three-storey conventional office buildings.

iii. To assess, the effectiveness of a courtyard on conserving energy at office buildings in Malaysia.

1.5 Research scope

The main motivation of this research is to offer indoor thermal conditions by using architectural and natural cooling strategies to reduce the indoor air temperature; also, it focused on lower energy consumption particularly on elements that related to mechanical cooling system. Conventional office buildings with single, double and three storeys that located in Kuala Lumpur and Johor were selected for the field measurement, the selected buildings had to be similar in the form of the courtyard, the total build area, the external envelope and the construction materials. Moreover, the number of persons accommodated in an office had to be similar. At last, the electricity in each building used in lighting, cooling systems beside office equipment's (desk computer, photocopy and printers).

This research is carried out using observation of a courtyard configuration and building layout, field measurement and (POE) questionnaire to evaluate the users' perception towards indoor thermal conditions, thus; to audit energy consumption in each building using electricity bills. Furthermore, a review of common research that conducted the courtyard as natural cooling methods and the tool that selected discussed in the following chapter.

1.6 Significance of research

Minimize heat gained is an important concept of building design of many regions; it is a serious economical aspect in terms of the first cost and operating cost. Over various methods to provide indoor thermal condition of buildings directed by using the courtyard area, several authors demonstrated that the air temperature in courtyard building is lower than the outer atmosphere.

The significance of this research appears through the reflection of courtyard area on providing comfort conditions, which could cause a positive impact on the occupants' health and productivity, besides lowering the building operating cost by minimizing the total energy that used to offer indoor comfort.

1.7 Structure of the thesis

The research organized into five chapters and eleven appendices.

i. **Chapter 1 Introduction:** Described motivations, problem statement and objectives for this study.

ii. **Chapter 2 Literature Review:** Includes background on the courtyard types in different parts of the world, their historical evolution, and the basic forms along with the benefits. Furthermore, an overview of courtyard building types in Malaysia over three buildings type was added as a part of research objective. Furthermore, two parts of this study were investigated (energy consumption in office buildings and human thermal comfort). The chapter reports previous studies that conducted the effect of the courtyard as passive cooling strategies.

iii. **Chapter 3 Research Design and Methodology:** It is the descriptive part of the research. It describes the procedure or the methodology that adapted, and the characteristic of selected buildings. Moreover, the criteria that used for evaluation the environmental measurement and post-occupancy evaluation (POE).

iv. **Chapter 4 Data Analysis and Results:** This chapter presents the main research work detailing the research analyzing the measurement process and the questionnaire. The chapter provides the results and the validation of assessment the courtyard area and building layout; the result of environmental measurement, the result of POE questionnaire and the results of evaluate the energy consumption.

v. **Chapter 5 Conclusion and Recommendation:** Conclusion and recommendations are providing for consideration in future research of courtyard area at an office building.

vi. **The appendices** include case studies layouts, the environmental measurement, the questionnaire and table of electrical bills.

1.8 Summary

Nowadays the scientists around the world focused on the adapting methods that conserve the energy, this is mainly due to a probable future energy shortage as well as global warming. On the building sectors, engineers attempted to afford energy saving and sustainable strategies by adopting old passive cooling techniques. Ultimately, the courtyard is one of the traditional architectural that used to enhance natural cooling inside buildings, which it leads to offer indoor thermal comfort and conserving energy. Thus, courtyards in this research are under investigation in contemporary office buildings with single, double and three storeys.

The next chapter presents the literature review of the historical background of the courtyard. Thus, it deals with the courtyard type's identification in different parts of the world, their historical evolution, the basic courtyard forms, and the benefits and liabilities associated with these forms. Thus, it illustrates a review of energy consumption in an office building and indoor environmental quality in office building. In addition, it reports earlier studies conducted at courtyard building as passive cooling strategies in different climates.

REFRENCES

Abdul Rahman, H., Wang, C., Kamaruzzaman, S. N., Mohd-Rahim, F. A., Mohd-Danuri, M. S., & Lee, K. (2014). Case Study of Facility Performance and User Requirements in the University of Malaya Research and Development Building. *Journal of Performance of Constructed Facilities, 29*(5), 04014131.

Abdul Shukor, A., & Young, A. (1993). *Thermal comfort study as an aid to determine energy savings in buildings in Malaysia.* Paper presented at the Proceedings of Energex 93–The 5th International Energy Conference.

Abu-Bakar, S. K. (2013). *An evaluation of passive cooling strategies on indoor thermal performance of an office space.*Unversiti Tun Hussien Onn Malaysia: Master's Thesis.

Ahmad, A. (2004). *Case study: Thermal comfort study demonstration low energy office (LEO).* University of UKM, Malaysia: Master's Thesis.

Ahmad, A. S., Hassan, M. Y., Abdullah, H., Rahman, H. A., Majid, M. S., & Bandi, M. (2012). *Energy efficiency measurements in a Malaysian public university.* Paper presented at the Power and Energy (PECon), 2012 IEEE International Conference on.

Ahmadi, A. R. a. (2004). *Tamadun rumpun budaya Melayu*: Kementerian Kebudayaan, Kesenian dan Warisan Malaysia.

Al-Azzawi, S. (1994). Indigenous courtyard houses: A comprehensive checklist for identifying, analysing and appraising their passive solar design characteristics Regions of the hot-dry climates. *Renewable energy, 5*(5), 1099-1123.

Al-Dawoud, A. (2006). *Comprative Analysis of Energy Performance Between Courtyard and Atriumin Building* Illinois Institute of Technology: PH.D Thesis.

Al-Hemiddi, N. A., & Al-Saud, K. A. M. (2001). The effect of a ventilated interior courtyard on the thermal performance of a house in a hot–arid region. *Renewable energy, 24*(3), 581-595.

Al-Tamimi, N. A., & Fadzil, S. F. S. (2011a). The potential of shading devices for temperature reduction in high-rise residential buildings in the tropics. *Procedia Engineering, 21*, 273-282.

Al-Tamimi, N. A., M Fadzil, S. F. S., & Harun, W. M. W. (2011b). The effects of orientation, ventilation, and varied WWR on the thermal performance of residential rooms in the tropics. *Journal of sustainable development, 4*(2), 142.

Aldawoud, A. (2008). Thermal performance of courtyard buildings. *Energy and Buildings, 40*(5), 906-910.

Almhafdy, A., Ibrahim, N., Ahmad, S. S., & Yahya, J. (2013a). Analysis of the Courtyard Functions and its Design Variants in the Malaysian Hospitals. Procedia-Social and Behavioral Sciences, 105, 171-182. doi: 10.1016/j.sbspro.2013.11.018

Almhafdy, A., Ibrahim, N., Ahmad, S. S., & Yahya, J. (2013b). Courtyard Design Variants and Microclimate Performance. *Procedia-Social and Behavioral Sciences, 101*, 170-180.

Andamon, M. M. (2006). *Thermal comfort and building energy consumption in the Philippine context.* Paper presented at the PLEA 2006-The 23rd Conference on Passive and Low Energy Architecture.

Andreasi, W. A., & Lamberts, R. (2006). Thermal comfort in buildings located in regions of hot and humid climate of Brazil. *Proc Comfort and Energy Use in Buildings-Getting them Right. London: Network for Comfort and Energy Use in Buildings*.

Ani, A., Mohamed, N., & Abdul Rahman, N. (2012). Socio-cultural influences in the composition of traditional Malay house compounds in rural Melaka. *ALAM CIPTA, International Journal on Sustainable Tropical Design Research & Practice, 5*(1), 63-78.

ASHRAE. (2001). Thermal Comfort in ASHRAE Handbook. American Society of Heating, Refrigerating and Air-Conditioning Engineers, Atlanta,111

ASHRAE. (2004). Thermal Environmental Conditions for Human Occupancy. American Society of Heating, Refrigerating and Air-Conditioning

Engineers, Atlanta, 55-92

ASHRAE. (2009). Fundamentals Handbook *IP Edition*. American Society of Heating, Refrigerating and Air-Conditioning

Engineers, Atlanta, Inc.

Attia, S. (2006). *The role of landscape design in improving the microclimate in traditional courtyard buildings in hot arid climates.* Paper presented at the 23rd International Conference on Passive and Low Energy Architecture-PLEA 2006.

Auliciems, A., & Szokolay, S. V. (2007). *Thermal comfort (2nd edition)*. PLEA: Passive and Low Energy Architecture International with association with Department of Architecture, The University of Queensland.

Ayhan, B., & Neslihan, D. (2011). The influence of climate and privacy on indigenous courtyard houses in Diyarbakır, Turkey. *Scientific Research and Essays, 6*(4), 908-922.

Azuan, Z. M., & Ismail, L. H. (2012). Natural Ventilation Approached on Circular Courtyard. The International Conference on Civil and Environmental

Engineering Sustainability (IConCEES 2011), 3-5 April 2012, Johor Bahru, Malaysia.

Bagneid, A. (2006). *The creation of a courtyard microclimate thermal model for the analysis of courtyard houses.* Texas A&M University.

Bakar, N. N. A., Hassan, M. Y., Abdullah, H., Rahman, H. A., Abdullah, M. P., Hussin, F., & Bandi, M. (2015). Energy efficiency index as an indicator for measuring building energy performance: A review. *Renewable and Sustainable Energy Reviews, 44*, 1-11.

Barlow, S., & Fiala, D. (2007). Occupant comfort in UK offices—how adaptive comfort theories might influence future low energy office refurbishment strategies. *Energy and Buildings, 39*(7), 837-846.

Bloom, J. (2009). *The Grove encyclopedia of Islamic art and architecture*: Oxford University Press.

Bridson, D. (2012). Courtyard Housing Study- Djingis Khan and The Kingo Houses. Retrieved from website: http://www.stadsbyggnad.lth.se/fileadmin/stadsbyggnad/images/student_work/Landscape_and_gardens/Danny_Bridson_-_Courtyard_Housing_Study.pdf

Cantón, M. A., Ganem, C., Barea, G., & Llano, J. F. (2014). Courtyards as a passive strategy in semi dry areas. Assessment of summer energy and thermal conditions in a refurbished school building. *Renewable energy, 69*, 437-446.

Charles, K. E. (2003). Fanger's thermal comfort and draught models. Ottawa, Canda: National Research Council Canda.

Chee, V. (1998). Houses: 1957–1987 (or 30 Years of Dreams Fulfilled?). *Post Merdeka Architecture Malaysia 1957-1987*, 31-36.

Chen. (1998). *The Encyclopedia of Malaysia: Architecture*: Archipelago Press. Brooklyn, NY

Chen, K., Rys, M., & Lee, E. S. (2006). Modeling of thermal comfort in air conditioned rooms by fuzzy regression analysis. *Mathematical and computer modelling, 43*(7), 809-819.

Cho, S., & Mohammadzadeh, N. (2013). Thermal Comfort Analysis Of a Traditional Iranian Courtyard For The Design Of Sustainable Residential Buildings. *13th Conference of International Building Performance Simulation Association*.

Chun, H. K., & Noordin, N. M. (2005). *An influence of colonial architecture to building styles and motifs in colonial cities in Malaysia.* Paper presented at the 8th International Conference of the Asian Planning Schools Association.

CIBSE. (1978). CIBSE Guide A: Enverionmental Criteria for Design. Chartered Institution of Building Service Engineers: London.

Corrado, V., Serra, V., & Vosilla, A. (2004). *Performance analysis of external shading devices.* Paper presented at the Proceedings of PLEA.

Daghigh, R., Adam, N. M., Sopian, K., & Sahari, B. (2009). Thermal comfort of an air-conditioned office through different windows-door opening arrangements. *Building Services Engineering Research and Technology, 30*(1), 49-63.

Dahlan, N., Jones, P., Alexander, D., Salleh, E., & Dixon, D. (2008). Field measurement and subjects' votes assessment on thermal comfort in high-rise hostels in Malaysia. *Indoor and Built Environment, 17*(4), 334-345.

Darus, A. Z. M., & Hashim, N. A. (2012). *Sustainable Building in Malaysia: The Development of Sustainable Building Rating System*: INTECH Open Access Publisher.

Das, N. (2006). *Courtyards houses of Kolkata: Bioclimatic, typological and socio-cultural study.* Kansas State University.

De Dear, R., Leow, K., & Foo, S. (1991). Thermal comfort in the humid tropics: field experiments in air conditioned and naturally ventilated buildings in Singapore. *International Journal of Biometeorology, 34*(4), 259-265.

Douglass, D. (2015). AD Classics: Menara Mesiniaga / T. R. Hamzah & Yeang Sdn. Bhd. . Retrieved 10 August, 2016, from http://www.archdaily.com/774098/ad-classics-menara-mesiniaga-t-r-hamzah-and-yeang-sdn-bhd

Edwards, B. (2006). *Courtyard Housing: Past, Present and Future*. New York, NY: Taylor & Francis.

Energy Commission. (2009). Annual Report. Retrieved March 15, 2015, from http://www.st.gov.my/v4/

Energy Commission. (2011). Annual Report. Retrieved March 17, 2015, from http://www.st.gov.my/v4/

Ganea, S. (2016). Traditional Courtyard House Reinvented In Malaysia. Retrieved August 10, 2016, from http://www.homedit.com/traditional-courtyard-house/

GhaffarianHoseini, A., Berardi, U., Dahlan, N. D., & GhaffarianHoseini, A. (2014). What can we learn from Malay vernacular houses? *Science Direct, 157–170*. doi: 10.1016/j.scs.2014.04.008

Ghaffarianhoseini, A., Berardi, U., & Ghaffarianhoseini, A. (2015). Thermal performance characteristics of unshaded courtyards in hot and humid climates. *Building and Environment, 87*, 154-168.

Gratia, E., Bruyere, I., & De Herde, A. (2004). How to use natural ventilation to cool narrow office buildings. *Building and Environment, 39*(10), 1157-1170.

Habba, A. (2012). Contemporary Vernacular -The shifting definitions. Retrieved June 5, 2015, from https://amimahabba.wordpress.com/2012/01/25/contemporary-vernacular-the-shifting-definitions/

Hien, W. N., & Istiadji, A. D. (2003). *Effects of external shading devices on daylighting and natural ventilation.* Paper presented at the Proceedings of the 8th International IBPSA Conference, Eindhoven, The Netherlands.

Hoyt, T., Schiavon, S., Piccioli, A., Moon, D., & Steifeld, K. (2013). CBE Thermal Comfort Tool. Retrieved 25 December, 2014

Huat, N. B., & Akasah, Z. A. (2011). An overview of Malaysia green technology corporation office building: A showcase energy-efficient building project in Malaysia. *Journal of sustainable development, 4*(5), p212.

Hui, S. C. M. (1997). Introduction to Energy Efficient Building Design - Environmental Controls. *Department of Architecture, The university of Hong Kong*.

Hussain, N. M., & Ahmad, S. (2010). Malay Landscape: Typical Design for Contemporary House at Desa Wawasan. *Asian Journal of Environment-Behaviour Studies, 1*(3), 38-47.

Indraganti, M., Ooka, R., & Rijal, H. (2012). Significance of air movement for thermal comfort in warm climates: a discussion in Indian context. *Actes du congrès du Network on Comfort and Energy Use in Buildings «The changing context of comfort in an unpredictable world*.

Ismail, Karagaratnan, & Kadirgama. (2013). Thermal comfort findings: Scenario at Malaysian automotive industry. *Thermal Science, 17*(2), 387-396.

Ismail, L. H. (2007). *An Evaluation of Bioclimatic High Rise Office Buildings in Tropical Climate-Energy Consumption and Users' Satisfaction in Selected Office Buildings in Malaysia.* University of Liverpool: Ph.D. Thesis.

Ismail, N. A. (2002). Design Paradigm: Sustaining Responsive Cultural Landscape of Malay Rural Residential Area. *International Seminar on Vernacular Settlement*, 316-323.

ISO. (1994). ISO 7730-1994 *Moderate thermal environments—determination of the PMV and PPD indices and specification of the conditions for thermal comfort." Geneva: International Organization for Standardization*.

Jones, P. B. (1999). *Hugo Häring: the organic versus the geometric*: Edition Axel Menges.

Jong, S. L., D'Amico, M., Din, J., & Lam, H. Y. (2014). Analysis of Fade Dynamic at Ku-Band in Malaysia. *International Journal of Antennas and Propagation, 2014*, 7.

Ju, S., & Omar, S. (2011). A Typology Of Modern Housing In Malaysia 1st South East Asia Housing Forum of ARCH, 6-7 October 2011. *Seoul, Korea*.

Ju, S. R., Omar, S., & Ko, Y. E. (2009). Modernization of Traditional Malay House in the Kampong Baharu (Kuala Lumpur). *GEST (Green Tech, Eco Life & Sustainable Architecture for the Cities of Tomorrow)*.

Khalil, N., & Nawawi, A. H. (2009). Performance analysis of government and public buildings via post occupancy evaluation. *Asian Social Science, 4*(9), 103.

Lau, S. S., & Yang, F. (2009). Introducing healing gardens into a compact university campus: design natural space to create healthy and sustainable campuses. *Landscape Research, 34*(1), 55-81.

Lee, V. (2013). Sustainability in The Built Environment: A Case Study. Retrieved August 10, 2016, from http://lychanhvinh-1007z74679.weebly.com/1/category/all/1.html

Ludin, A. N. M., & Barau, A. S. (2011). Industrial Agitation vs. Climate Disruption: Flood Vulnerabilities & Spatial Planning in Iskandar Metropolis (Geographical Data). Retrieved August 13, 2016, from http://start.org/download/car2/1-ludin.pdf

Lyons, P., Arasteh, D., & Huizenga, C. (2000). Window performance for human thermal comfort. *Transactions-American Society of Heating Refrigerating and Air Conditioning Engineers, 106*(1), 594-604.

Mahaek, E. (2003). *Solar Effective Envelope Design Advisor (SEEDA)*. Illinois, Chicago: Illinois Institute of Technology.

Meir. (2000). *Courtyard microclimate: A hot arid region case study.* Paper presented at the Architecture City Environment, Proceedings of the 17th PLEA International Conference, Cambridge, James & James, London, pp218–223.

Meir, Pearlmutter, & Etzion. (1995). On the microclimatic behavior of two semi-enclosed attached courtyards in a hot dry region. *Building and Environment, 30*(4), 563-572.

MMD. (2014). MalaysiaMeterorogical Department. Retrieved 25 February, 2015, from http://www.met.gov.my.

Moghimi, S., Zaharim, A., & Sopian, K. (2011). *Building energy index (BEI) in large scale hospital: case study of Malaysia*. Energy Efficiency, 7(2), 243-256.

Morton, E. L. (1990). *Courtyard housing, a solution for high-density, low-rise single-family housing in the US.* Massachusetts Institute of Technology.

MS1525. (2001). Standard: 1525 Code of Practice on Energy Efficiency and Use of Renewable Energy for Non-residential Buildings. Malaysia.

Muhaisen, A. S. (2006). Shading simulation of the courtyard form in different climatic regions. *Building and Environment, 41*(12), 1731-1741. doi: 10.1016/j.buildenv.2005.07.016

Nasir, A. H., & Teh, H. H. W. (2011). *The traditional Malay house*. Shah Alam, Malaysia: ITBM. Understood and learned the basic typologies of a Malay vernacular house.

Nicol, F. (1993). *Thermal comfort: a handbook for field studies towards an adaptive model*: University of East London, London.

Noble, A. G. (2007). *Traditional buildings: a global survey of structural forms and cultural functions* (Vol. 11): IB Tauris.

Olesen, B. W., & Parsons, K. (2002). Introduction to thermal comfort standards and to the proposed new version of EN ISO 7730. *Energy and Buildings, 34*(6), 537-548.

Oliver, P. (2003). *Dwelling: The House across the world*. Oxford: Phaidon Press Ltd.

Petruccioli, A. (2006). The courtyard house: typological variations over space and time. *Courtyard Housing: Past, Present and Future*, 3-20.

Polyzoides, S., Sherwood, R., & Tice, J. (1992). *Courtyard Housing in Los Angeles*: Princeton Architectural Press.

Preiser, W. F. (1995). Post-occupancy evaluation: how to make buildings work better. *Facilities, 13*(11), 19-28.

Puteh, M. S. B. (2007). *Energy Efficiency In Office Building Practical Case Study.* (Bachelor), Universiti Teknikal Malaysia Melaka.

Rajapaksha, I., Nagai, H., & Okumiya, M. (2003). A ventilated courtyard as a passive cooling strategy in the warm humid tropics. *Renewable energy, 28*(11), 1755-1778.

Rajapaksha, U., & Hyde, R. (2002). *Passive modification of air temperature for thermal comfort in a courtyard building for Queensland.* ", in Levin. H (ed), Indoor Air 2002, Proceedings of the 9 th International Conference on Indoor Air Quality and Climate, Monterey, California, June 30-July 5 2002, Vol. 2, pp: 860-866

Raman, M. (2009). Mitigating climate change: what America's building industry must do. *Design intelligence.* Retrieved March 25, 2015, from http://www.di.net/articles/mitigating-climate-change-what-americas-building-industry-must-do/

Razman, R. B., Abdullah, A. H. B., & Wahid, A. Z. B. A. (2011). *Study On Thermal Comfort In University Hostel Building Case Study At Universiti Tun Hussein Onn Malaysia (UTHM), Batu Pahat.* Paper presented at the Proceedings of International Conference on Environment Science and Engineering (ICESE 2011).

RichezAssocies. (2013). Architecture urban design landscape architecture. Retrieved August 10, 2016, from http://www.richezassocies.com/fr/projet/398/la-ville-nouvelle-de-putrajaya

Rust, C. (2010). Design for Healthcare. the United States of America. *Renee Wilmeth*.

Sadafi, N., Salleh, E., Haw, L. C., & Jaafar, Z. (2011). Evaluating thermal effects of internal courtyard in a tropical terrace house by computational simulation. *Energy and Buildings, 43*(4), 887-893.

Sadafi, N., Sallen, E., Haw, L. C., & Jaafar, Z. (2008). Potential Thermal Impacts of Internal Courtyard in Terrace Houses: A Case Study in Tropical Climate. *Journal of Applied Sciences, 8*(15), 2770-2775.

Sadeghifam, A. N., Zahraee, S. M., Meynagh, M. M., & Kiani, I. (2015). Combined use of design of experiment and dynamic building simulation in assessment of energy efficiency in tropical residential buildings. *Energy and Buildings, 86*, 525-533.

Safarzadeh, H., & Bahadori, M. (2005). Passive cooling effects of courtyards. *Building and Environment, 40*(1), 89-104.

Saidur, R. (2009). Energy consumption, energy savings, and emission analysis in Malaysian office buildings. *Energy Policy, 37*(10), 4104-4113.

Schoenauer, N., & Seeman, S. (1962). *The court-garden house*: McGill University Press Montreal.

Shafaghat, A., Keyvanfar, A., Majid, M. Z. A., Lamit, H. B., Ahmad, M. H., Ferwati, M. S., & Ghoshal, S. K. (2016). Methods for adaptive behaviors satisfaction assessment with energy efficient building design. *Renewable and Sustainable Energy Reviews, 57*, 250-259.

Shaharon, M. N., & Jalaludin, J. (2012). Thermal Comfort Assessment-A Study Toward Workers Satisfaction in a Low Energy Office Building. *American Journal of Applied Sciences, 9*(7), 1037.

Shahidan, M. F., Mustafa, K., & Elias, S. (2007). *Effects of tree canopies on solar radiation filtration in a tropical microclimatic environment.* Paper presented at the PLEA2007 conference. Singapore.

Shashua-Bar, L., Pearlmutter, D., & Erell, E. (2009). The cooling efficiency of urban landscape strategies in a hot dry climate. *Landscape and Urban Planning, 92*(3), 179-186.

Sim, S. (2010). *Redefining the Vernacular in the Hybrid Architecture of Malaysia*. Victoria University of Wellington: Masters' Thesis.

Simons, B., Koranteng, C., Adinyira, E., & Ayarkwa, J. (2014). An Assessment of Thermal Comfort in Multi Storey Office Buildings in Ghana. *Journal of Building Construction and Planning Research, 2014*.

Statistic Department. (2010). Population Distribution and Basic Demographic Characteristic Report. Retrieved February 24, 2015, from http://www.statistics.gov.my/portal/index.

Stefanos, P., Roger, S., & James, T. (1996). *Courtyard Housing in Los Angles: A Typological Analysis*: Princeton Architecture Press.

Sthapak, S., & Bandyopadhyay, A. (2014). Courtyard houses: An overview. *Recent Research in Science and Technology, 6*(1).

Szokolay, S. (2000). Dilemmas of warm-humid climate house design: heavy vs. lightweight and cooling effect of air movement. K.Steemers and S. Yannas, Architecture City Environment: Proceeding of PLEA 2000., Cambridge, UK, (144-149).2-5 July,2000.

Tablada, A., Blocken, B., Carmeliet, J., De Troyer, F., & Verschure, H. (2005). Geometry of building's courtyard to favour natural ventilation comparsion between wind tunnel expermint and numerical simulation. Proceedings of Sustainable building conference. Sustainable Building SB05,Tokyo, September 2005, 8-8.

Taib, N., Abdullah, A., Fadzil, S. F. S., & Yeok, F. S. (2010). An assessment of thermal comfort and users' perceptions of landscape gardens in a high-rise office building. *Journal of sustainable development, 3*(4), p153.

Taleghani, M., Tenpierik, M., & van den Dobbelsteen, A. (2012). Environmental impact of courtyards-a review and comparison of residential courtyard buildings in different climates. *College Publishing, 7*(2), 113-136.

Tariq, M. (2011). *Campus planning and design: exploring the programmatic elements involved in creating residential campus courtyards.* (Master of Landscape Architecture), Mississippi State University, Mississippi.

Tebbut, L. (2015). Fabian Tan's Ittka House is designed to offer respite from Malaysian heat. Retrieved August 10, 2016, from http://www.dezeen.com/2015/10/05/fabian-tan-ittka-house-kuala-lumpur-malaysia-tree-courtyard/

Toone, T. L. (2008). *Effect of healing garden use on stress experienced by parents of patients in a pediatric hospital.* Texas A&M University: Masters' Thesis.

Ünver, R., Akdağ, N. Y., Gedik, G. Z., Öztürk, L. D., & Karabiber, Z. (2004). Prediction of building envelope performance in the design stage: an application for office buildings. *Building and Environment, 39*(2), 143-152.

Wagner, A., Gossauer, E., Moosmann, C., Gropp, T., & Leonhart, R. (2007). Thermal comfort and workplace occupant satisfaction—Results of field studies in German low energy office buildings. *Energy and Buildings, 39*(7), 758-769.

Wahab, I. A., & Ismail, L. H. (2014). Contemporary House with Vernacular Elements Effect on Natural Ventilation in Tropical Climate. *International Journal for Research and Emerging Science, 1(5).*

Wee, K. F., Matsumoto, H., Ho, C. S., & Yu, F. L. (2008). Energy consumption and carbon dioxide emission considerations in the urban planning process in Malaysia. Retrieved July 25, 2015, from https://core.ac.uk/download/files/392/11782692.pdf

Wong, N., & Li, S. (2007). A study of the effectiveness of passive climate control in naturally ventilated residential buildings in Singapore. *Building and Environment, 42*(3), 1395-1405.

Wong, N. H., & Peck, T. T. (2005). The impact of vegetation on the environmental conditions of housing estates in Singapore. International Journal on Architecture Science, 6(1), pp.31-37.

Wu, Z. (2011). *Evaluation of a sustainable hospital design based on its social and environmental outcomes.* (Master), Cornell University.

YEE, T. C. (2014). Indoor Environmental Quality (IEQ): a Case Study in Taylor's University, Malaysia. *International Journal of Engineering, 5*(07), 8269.

Yousef, B. (2012). Thermal Comfort Study and Ventilation Evaluation of an Office. *Advances in Mechanical Engineering and its Applications, 3*(1), 278-283.

Yuan, L. J. (1984). Under one roof: The traditional Malay house. *IDRC Report, 12*(4), 15-16.

Yuan, L. J. (1991). *The Traditional Malay House: Indigenous and traditional knowledge and practices*: Institut Masyarakat, Phoenix Press.

Zainal, M., & Keong, C. (1996). *Thermal comfort and energy conservation in factory buildings.* Building Services Engineering Research and Technology. 30 (1)..49-63

Zakaria, A. Z., Salleh, I. H., & Rashid, M. S. A. (2013). Landscape Furniture Present in the Ancient Malay Garden According to Old Manuscripts and their Effects on the Formation of Malay Garden Design Concept Model in Malaysia. *Procedia-Social and Behavioral Sciences, 91*, 28-35.

Zakaria, A. Z., Salleh, I. H., & Rashid, M. S. A. (2014). Identity of Malay Garden Design to be Promoted as the Cultural Tourism Product in Malaysia. *Procedia-Social and Behavioral Sciences, 153*, 298-307.

Zakaria, M. A., Kubota, T., & Toe, D. H. C. (2015). The Effects of Courtyards on Indoor Thermal Conditions of Chinese Shophouse in Malacca. *Procedia Engineering*, *121*, 468-476.